Letters to the Editor

Unjustified Interpretation of Flux Anomaly at the Transient Reactor Test Facility

Pinhole fuel-motion diagnostic data have been construed in a recent Note[1] to demonstrate a previously undetected large flux "anomaly" in the Transient Reactor Test Facility (TREAT). However, that conclusion is based on selected data, omits contradictory results, misplaces physical phenomena, and ignores the alternative of nonlinearity in pinhole instrument response as a cause of the anomaly. When the totality of the existing evidence is considered, the pinhole data anomaly is not validated as a reactor flux phenomenon.

Transient Data. The anomaly is derived from power- and background-normalized digital profiles of pinhole diagnostic system television-scan data taken during the PINEX-3 transient.[2] An unexpected time-varying increase of the power-normalized "radiation brightness" is cited as evidence along with similar effects in two other transients. Fuel-redistribution and power-normalization errors were ruled out in Ref. 1 as explanations for this anomalous intensity change.

The TREAT hodoscope fuel motion diagnostic system[3] was operated simultaneously with the pinhole system for five experiments. The hodoscope data in three experiments, including PINEX-3, for which there had been extensive exchange of information,[4] did not show—to a precision of a few percent—any time-dependent local perturbation correlated with transient rod motion. The pinhole anomaly is an order of magnitude larger than hodoscope sensitivity to this effect.

The pinhole system consisted of four gamma-ray imaging apertures stacked on top of each other in order to cover the necessary axial field of view (FOV); each channel had its own image intensifier and recording system. The top two scan lines that show positive anomalies are in FOV 2, while negative trends are common to FOV 3. Additional scan lines not shown in Ref. 1, but reported earlier,[4] indicate clearly that each of the four FOV instrument channels has a response that is uniform but sharply at variance with the adjacent FOV (taking into account FOV blending for overlap). A linear system would have a uniform gradient of single polarity across the four FOVs.

Image intensifier cameras of the type used for pinhole transient recording have some nonlinear behavior; in fact, this type of silicon-diode vidicon has a supralinear transfer characteristic for high-input light intensity.[5] The response of each of the four vidicons might be different in this regard. Because these scanning tube targets are composed of a matrix of discrete diodes, a low-duty cycle flashing light somewhere in the FOV would not necessarily assure linearity over the image array. Such alternative explanations for the anomaly should not be ignored in an assessment of the experimental data, particularly when the performance of the pinhole instrumentation has not been verified under the relevant dynamic conditions.[6]

A second possible explanation for the anomaly is associated with the low transient signal/background (S/B) ratio and the partitioned FOVs of the pinhole apparatus. Although line-by-line axial normalization should suppress flux tilt effects, a small error in background subtraction can make a minor real effect appear much larger; moreover, a small nonlinearity combined with a normalization error is subject to magnification in computation of signal strength. Given that the "transient data showed even larger changes (than the 15 to 20% steady-state rod-position-related effects) in the normalized fuel brightness,"[1] the specific magnitude of the pinhole anomaly apparently must be ~20%. If such an increase in measured total intensity ($S + B$) were interpreted to be entirely due to a signal change, the signal strength increase would be overestimated by a factor of 5.

Two other factors are suggestive of instrument nonlinearity: The reactor flux peaked in FOVs 2 and 3, where the largest signal changes occurred, and the pinhole data tracked the reactor power as well as or better than control rod motion.

Integral Data. Data taken with an integrating pinhole film detector are also invoked in Ref. 1 to sustain interpretation of the anomaly as a reactor phenomenon. The tabulated data show two common coupling-factor effects. One effect is a film exposure ratio having nearly a 20% difference for two rod position extremes; this ratio is consistent with the fission monitor wire data. The effect also agrees qualitatively with previously observed TREAT transient correction factors that have been attributed to transient rod changes.

The S/B ratio for pinhole film images is probably better by a factor of 3 or 4 than the transient images because of

[1] A. H. LUMPKIN and G. J. BERZINS, *Nucl. Sci. Eng.*, **81**, 477 (1982).

[2] D. R. PORTEN, F. J. MARTIN, and P. C. FERRELL, "Internal Fuel Motion as an Inherent Shutdown Mechanism for Hypothetical LMFBR Accidents: PINEX Series Experiments," *Proc. Topl. Mtg. Reactor Safety Aspects of Fuel Behavior*, Sun Valley, Idaho, August 2-6, 1981, Vol. 2, p. 218, American Nuclear Society (1981).

[3] A. DeVOLPI, C. L. FINK, G. E. MARSH, E. A. RHODES, and G. S. STANFORD, *Nucl. Technol.*, **56**, 141 (1982).

[4] D. R. PORTEN, P. C. FERRELL, and D. C. SMITH, Hanford Engineering Development Laboratory, Private Communication (1981).

[5] B. W. NOEL and A. J. YATES, *Rev. Sci. Instrum.*, **53**, 1762 (1982); see also "FPS-Videcon Television Cameras for Ultrafast-Scan Data Acquisition," LA-8236, Los Alamos National Laboratory (1980).

[6] A. DeVOLPI, "Applications of Cineradiography to Nuclear Reactor Safety," submitted to *Rev. Sci. Instrum.*

higher inherent sensitivity of the film and because time integration accumulates delayed as well as prompt fission gamma rays. Furthermore, photographic film has well-characterized relationships between density and exposure, making the results much less subject to nonlinearities of the type often found in active electronic instrument systems that are operated outside their normal range.

The other integral effect reported in Ref. 1 is an axial flux tilt, which appears in both the pinhole film and the monitor wire tabulations. The 5% tilt shows up when an axial fission density ratio is formed from the data collected during two extreme positions of control rod T1. This tilt might be real; in a pair of comparable single-pin experiments, the hodoscope observed an extreme transient background flux tilt of 5%. In any event, the integral data presented are not sufficiently definitive or relevant to constitute confirmation of a strong previously unrecognized flux anomaly during the PINEX-3 transient.

TREAT Power Coupling. An assortment of flux-related candidate explanations is offered[1] on behalf of the pinhole anomaly—control rod effects, Doppler broadening, fuel density changes, capsule heating, core temperature rises, and spectrum hardening. The integral steady-state data could be accounted for[7] by physical effects that depend on control rod core location and axial movement, but the pinhole transient data lack specific theoretical foundation; it might be entirely spurious, or it might be a small flux tilt magnified out of proportion.

Transient-correction factors in the TREAT program have long been recognized, and calibration experiments are routinely performed to make integral corrections. Even so, coupling-factor adjustments have little or no bearing on many measured properties: time or magnitude of temperature, flow, or pressure; hodoscope determination of time, location, and velocity of fuel motion; and quantitative estimates of fuel motion involved in transients. Interpretation, modeling, and intercomparisons based on fission energy deposition must, of course, take into account the method of instrumentation and normalization. Outside the limits of other systematic and statistical errors, any "misinterpretation"[1] of tests at TREAT would more likely result from inadequate understanding of test results and insufficient verification of pinhole instrumentation performance.

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[7]A. DeVOLPI, "Neutron-Flux, Power-Coupling, and Transient-Correction Factors at TREAT" (in preparation).

Response to "Unjustified Interpretation of Flux Anomaly at the Transient Reactor Test Facility"

In the preceding Letter,[1] DeVolpi asserts that our identification of the flux anomaly in the Transient Reactor Test Facility (TREAT) "is based on selected data, omits contradictory results, misplaces physical phenomena, and ignores the alternative of nonlinearity in the pinhole instrumentation response as a cause of the anomaly." He also makes a number of other, scientifically unfounded statements regarding our Note[2] and invokes hodoscope data as the contradictory evidence.

We welcome the opportunity to discuss any of the technical issues. In fact, we strongly feel that a thorough examination of these issues would be beneficial for all who interpret TREAT tests—be they experimenters, analysts, or diagnosticians, or those necessarily removed from immediate technical involvement. In our opinion, the potential for serious misinterpretation of data as a consequence of reactor physics related effects[3,4] is a most crucial issue for the entire fast reactor safety program.

It appears to us from the tone and content of DeVolpi's Letter that he does not understand the PINEX technique, does not recognize the value in internal, real-time calibration, and does not appreciate the advantages in characterizing and monitoring 4 instruments [the 4 television (TV) cameras of the PINEX] as opposed to 300 (the 300 plus hodoscope channels). We are reluctant to delve into inadequacies of the hodoscope system in this forum but feel that, because DeVolpi seeks to support his accusations by appealing to the hodoscope data, some discussion must be made.

We have prepared a lengthy, documented rebuttal to DeVolpi's ubiquitous, negative statements about our experiment. Such a lengthy discussion is perhaps inappropriate for a Letter to the Editor. Hence, we have summarized what, in our opinion, are the major issues. A full text dealing with all of the points, paragraph by paragraph, is available upon request.

First, we address the assertions that DeVolpi makes about our diagnostic system and its calibration. He claims that our TV camera tube had a matrix of discrete silicon diodes that exhibit a supralinear response, and that a pulsing light in the image scene would not provide a real-time gain monitor. The system we used in the experiment employs an antimony trisulfide target that is *not* a silicon matrix and has a sublinear transfer curve as shown in Fig. 1 (see DeVolpi's Ref. 5), a fact that has been known for years, and whose system gain has been shown to be characterizable by our pulsed light method.[5]

His statement that "... the performance of the pinhole instrumentation has not been verified under the relevant dynamic conditions" is simply incorrect.

[1]A. DeVOLPI, *Nucl. Sci. Eng.*, **83**, 316 (1983).

[2]A. H. LUMPKIN and G. J. BERZINS, *Nucl. Sci. Eng.*, **81**, 477 (1982).

[3]A. H. LUMPKIN and G. J. BERZINS, "Test Reactor Physics Effects on Fuel Motion Diagnostic Data Interpretation," *Proc. Int. Topl. Mtg. Liquid Metal Fast Breeder Reactor Safety and Related Design and Operational Aspects*, Lyon, France, July 19-23, 1982, European Nuclear Society (to be published); see also LA-UR-82-2028, Los Alamos National Laboratory (1982).

[4]A. H. LUMPKIN, "Further Comment on the Time-Dependent Neutron Flux/Spectrum Anomaly at the Transient Reactor Test Facility," Los Alamos National Laboratory (in preparation).

[5]G. J. YATES, Los Alamos National Laboratory, Private Communication (Sep. 1982); see also G. J. YATES and V. H. HOLMES, Jr., "Typical Vidicon Responses to Short-Duration Pulsed Light and Fast Single-Field Readout," LA-7026, Los Alamos National Laboratory (Mar. 1978); G. J. YATES and B. W. NOEL, "A 256-Line, 2.8-ns Field Duration TV Camera," LA-6407, Los Alamos National Laboratory (Nov. 1976).